Investigation 1

**To see how stopping distance is related to energy of movement**

A moving vehicle is stopped by brakes. The brakes grip the wheels of the vehicle. The friction of the brakes rubbing against the wheels turns the movement energy into heat. The brakes get hot, and the vehicle slows down, because the total amount of energy must remain constant. When all the movement (kinetic) energy has been turned into heat, the vehicle will stop.

We will test the theory that if the vehicle is moving faster (has more kinetic energy) it will take

further to stop. We will also find out whether the stopping distance is proportional to the speed of movement, or to the kinetic energy.

Kinetic energy of a moving object KE = ½ mv² where m – mass of vehicle and v = velocity.

The moving object will be a steel ball-bearing. We have three different sizes to choose from.

We will roll the ball-bearing down a v-shaped length of metal (aluminium). By rolling it from

different heights, we will give it different speeds.

We can choose between three surfaces of different types of carpet. The friction between the ballbearing and the carpet is what will slow it down. We need to find a way to make sure the ball goes smoothly from the ramp onto the carpet without bouncing or losing any of its energy.

**Preliminary tests**

When the ramp was very shallow, the ball didn’t run very far. If the ramp was too steep, the ball bounced when it reached the bottom. It lost energy and sometimes swerved off sideways. We decided that 30º was the steepest we could use.

We cut out a piece of plastic from a lemonade bottle and fixed it to the bottom of the ramp. It was fixed with sellotape and sand under it so that it didn’t move. It made a smooth curve for the ball to run off onto the carpet without losing energy.

The woolly carpet was too rough and stopped the ball very quickly. The smooth carpet let it roll right off the end. We chose a carpet with a sort of ridge pattern because the ridges kept the ball going straight, and it was rough enough to stop it quite quickly.

We used the heaviest ball-bearing to get most kinetic energy.

**Method:**

Set up the apparatus as shown

Put the ball on the ramp. Hold it in place with a finger. Hold the metre rule vertical beside the ramp (use a spirit-level to test). Move the ball backwards or forwards until the bottom of the ball is exactly the height to be tested. Let go of the ball. If it bounces or goes off course, do not count that test, but do it again. When it rolls straight, wait until it stops, then measure the distance it has gone. Repeat twice more for each height.

**Results**

The angle of the ramp was 30º

The length of the ramp was 130cm. We measured distances from the bottom of the curved plastic.

The ball-bearing weighed exactly 10.00g

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Expt | hight (cm) | Potential energy (mgh) (=kinetic energy) (J) | Distance taken to stop (cm) (to nearest cm) | | | |
| 1st time | 2nd time | 3rd time | Average time |
| 1 | 60 | 0.01 x 10 x 0.6 = 0.06 | 135 | 129 | 132 | 132 |
|  | 50 | 0.01 x 10 x 0.5 = 0.05 | 105 | 111 | 114 | 110 |
|  | 40 | 0.01 x 10 x 0.4 = 0.04 | 89 | 86 | 87 | 87 |
|  | 30 | 0.01 x 10 x 0.3 = 0.03 | 65 | 67 | **53** | 66 |
|  | 20 | 0.01 x 10 x 0.2 = 0.02 | 47 | 40 | 42 | 43 |
|  | 10 | 0.01 x 10 x 0.1 = 0.01 | 20 | 23 | 21 | 21 |

**Conclusion from the graph**

The graph shows the average result for each height, with used. The graph is a straight line from the origin (no movement = no distance to stop). The distance needed to stop is directly proportional to the kinetic energy of the rolling ball.

This was what I predicted to start with. If the braking force is constant, the rate of transfer of

energy will also be constant, so more energy needs more distance to stop. We had to assume that the carpet gave the same resistance all the way along its length, and it looks as if this is true.

In a real vehicle, this doesn’t work so well, because the brakes get very hot and hot brakes are less efficient. To test that stopping distance is not proportional to speed, I calculated the velocity of the ball each time. I assumed that there was no friction loss on the ramp, so all the potential energy of lifting the ball onto the ramp would turn into kinetic energy as it rolled down. Both the ball and the ramp are very smooth, so this is a fair approximation.

KE = ½ m v²

|  |  |  |  |
| --- | --- | --- | --- |
| Drop height (cm) | KE (J) | Speed (ms-1) | Stop distance |
| 60 | 0.6 | 3.46 | 132 |
| 50 | 0.5 | 3.16 | 110 |
| 40 | 0.4 | 2.83 | 87 |
| 30 | 0.3 | 2.45 | 66 |
| 20 | 0.2 | 2.00 | 43 |
| 10 | 0.1 | 1.41 | 21 |

**Evaluation:**

The preliminary tests showed that the ball only rolled about the same distance to a few centimeters each time, so we only measured to the nearest centimetre. This was good enough for me to find a clear pattern in the results. We could measure to the nearest millimetre, but we would have to remember to always measure to the same place on the ball, exactly where it touches the carpet.

We had to bend down to get level with the ruler when measuring the start height so that there would not be a parallex error. We measured to the bottom of the ball because this comes down to ground level at the end.

The ball almost always rolled straight because of the pattern on the carpet. All of the carpet was quite new and it seemed to give the same force all the way along. Only one result went wrong and I did not include this in the average for that height.

The graph shows that the results are consistent and reliable. Because I have a lot of data and it all agrees, I am confident that the stopping distance is directly proportional to the kinetic energy of the ball, and not to its speed.